Lecture 12, Feb 24, 2005

Learn:

1. The definition of temperature T and heat Q and how to distinguish between them.
2. The definition of specific heat capacity, latent heats and the calorie.
3. The definitions of Farrenheit, Celcius and Kelvin temperature scales.
4. The first law of thermodynamics.
5. The equation of state for an ideal gas.
6. The distinction between conduction, convection and radiation as methods of heat transfer.

Understand:

1. How to measure T and how to express the results on the three T scales.
2. How the difference in specific heat of substances leads to different T changes for a given amount of heat transfer.
3. How the latent heats are involved in changes in state.
4. How to use the first law of thermodynamics.
5. How heat transfer is achieved in the processes of conduction, convention, and radiation.

Heat is a form of energy, and it has long been known that heat energy will naturally flow

A. from cold to hot objects.
B. from hot to cold objects.
C. only from solids to liquids.
D. only from liquids to solids.
E. only from gases to solids and liquids.

The amount of heat is often measured in calories. If I add 1 calorie of heat energy to 1 gram of water, the temperature of the water will

A. decrease by 1°C.
B. decrease by 1°F.
C. stay the same since water has a very high specific heat.
D. increase by 1°C.
E. increase by 1°F.

The temperature of a substance is

A. proportional to the average kinetic energy of the molecules in a substance.
B. equal to the kinetic energy of the fastest moving molecule in the substance.
C. proportional to the lowest kinetic energy available to a molecule.
D. proportional to the average momentum of the fastest 50% of the molecules in the substance

---

On a cold winter's morning you awake and step out of bed. One foot is on the tile floor and the other is on a rug on the floor. Which statement is true?

A. The tile feels colder than the rug because it really is colder than the rug
B. Heat flows from the rug, thru your body and out to the tile - thus the tile feels cold compared to the rug
C. The tile feels colder than the rug, because compared to the rug, the tile conducts heat more rapidly away from your foot.
D. Actually there is no difference between the rug and the tile so any sensation you experience is imaginary.

Which of the following temperatures is the lowest?

A. 0°C B. 0°F C. 263 K D. All are the same.

A physics student has to make a choice in the color of shingles to put on her house. Considering only energy cost in heating and cooling the house, the decision of a light versus dark color roof will be based upon which of the following?

A. A dark roof would be better in the winter but worse in summer.
B. A light roof would be better in the winter but worse in summer.
C. A light roof would be better in both the winter and summer

---

Review: First Law Thermodynamics (I)

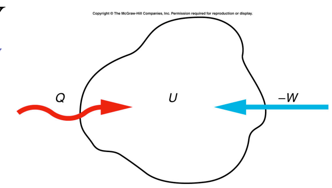
Lecture 12

- Heat is a form of energy
- Internal Energy is the sum of kinetic and potential energies of all atoms and molecules in a substance

The change in internal energy of a substance equals the heat transferred to it - the work done by it.

$$\Delta U = Q - W$$

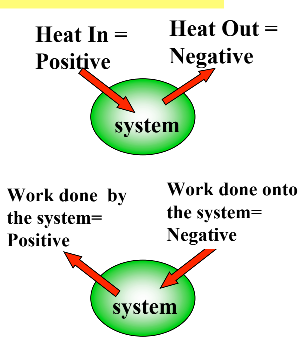
U=internal energy
Q=heat
W=work



Review: First Law Thermodynamics (II)

Change in internal energy = Heat – Work

- Heat is positive when is added to the system (it will increase the energy)
- Work is positive when is done by the system (it will be subtracted so it will decrease the energy)



Metabolic Rate

- Humans are open systems where the mass brought into the body through eating increases the internal energy through metabolism. The metabolic rate is the rate internal energy is transformed to heat and work: $\Delta U = Q - W$

Typical Metabolic Rates

Sitting	**115 Watts=115 J/s**
Running	**1150 Watts**
Sleeping	**70 Watts**

1g of fat=10Kcal=40,000J **1lb of fat=18,000,000J**

To loose a pound you have to sit for 43hours or run a marathon!

Adiabatic Processes

- Process where **no heat** enters or leaves the system. In short **Q=0**
- In this case the first law of thermodynamics is:

Change in internal energy = –Work

- An example of adiabatic process is the compression or expansion of a gas
  - If the work is done by the system like in the expansion it is positive and will decrease the energy
  - If work is done into the system like in the gas compression is negative therefore it will increase the energy -(-W) = +W

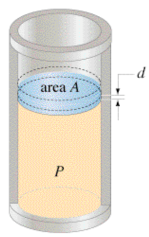
Pressure (Review)

- Pressure is force per unit area

p=F/A

- Units of pressure:
  - English psi=lb/in^2 (psi=pounds per square inch)
  - Metric Pa=N/m^2 (Pa=Pascal)
- Atmospheric pressure=14.7psi = 101,000Pa

Gas Expansion



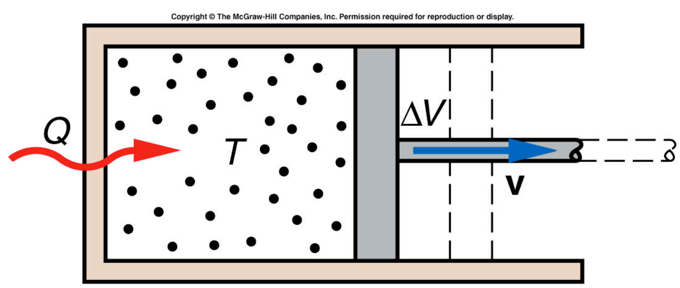
- Consider a gas volume that expands by pushing on a piston.
- If the process is isobaric, P is constant and then

- **W = Fd = PAd.**

W = P DV = P(V_f - V_i)

Work done = Pressure x Change in Volume

Gas behavior and the first law



$$W = P\,\Delta V$$

$$PV = NkT$$

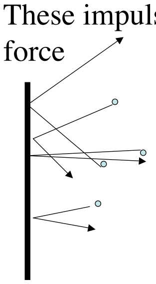
Boyle's Law

- An ideal gas is a gas where
  - The molecules do not interact with each other
  - The molecules occupy a small portion of the volume
- Most gasses at room temperature and atmospheric pressure are close to ideal
- For an ideal gas **at a fixed temperature**, Boyle's law applies:

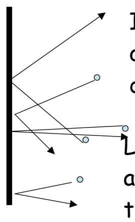
pV=constant

Pressure in an Ideal Gas

- The pressure an ideal gas exerts on a surface is the result of a huge number of molecules bouncing off of the surface.
- These impulses merge into a continuous force

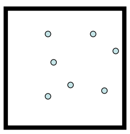


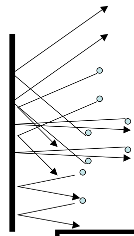
Pressure Changes in an Ideal Gas

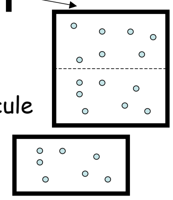


If you double the number of molecules, The pressure doubles.

Likewise, if you compress a piece of gas but, keep the temperature the same to half the volume, it will exert twice the pressure because the chance of a molecule will hit a patch of the surface doubles







Changes in an Ideal Gas

- Let us suppose we have some gas confined to a volume and we double the average velocity of the molecules
- The molecules will collide with a surface twice as frequently
- The impulse of the collisions will be twice as large
- Thus, the pressure will be four times as great.
- The average kinetic energy is proportional to v^2 since $K=mv^2/2$, thus also four time as great.
- Pressure is thus directly proportional to (absolute) temperature.

Ideal Gas Law

- Pressure is thus directly proportional to (absolute) temperature. More generally, for an ideal gas,

$$pV = NkT$$

where $k = 1.38 \times 10^{-23}$ J/°K.

Where

k=Boltzmann's constant
N=number of molecules

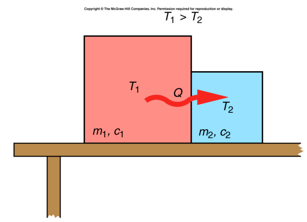
- The ideal gas law can be written as

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

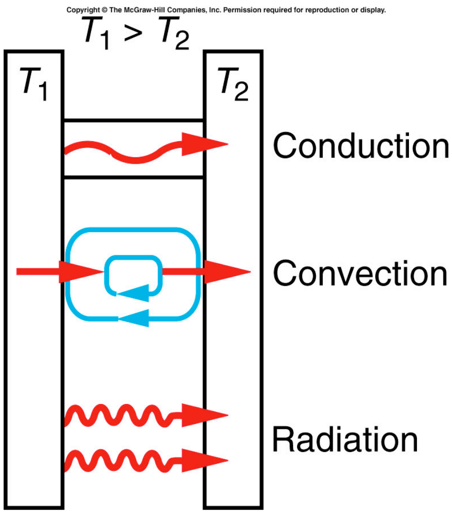
For this equation you need absolute temperatures (K)

Heat

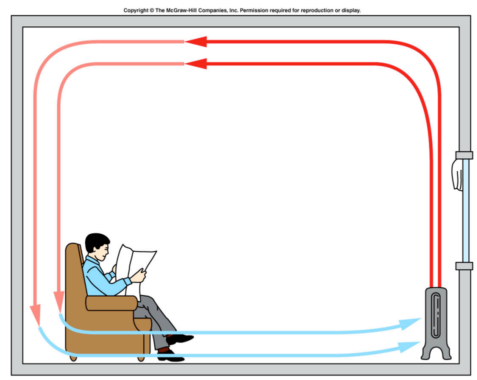
- **Heat** is the form of energy which is transferred between two substances because they are at different temperature.



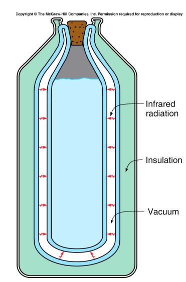
- Heat can be transferred by
  - **Conduction**: Objects in physical contact
  - **Convection**: Heat carried by the motion of a fluid
  - **Radiation**: Heat carried by electromagnetic radiation



Convection



Radiation



Class Exercise # 5 - Feb. 24, 2005

(Write your name and section number)

Let us suppose that we have a pot filled with 1 kg of ice at -10ºC and put it on a stove which delivers heat at a rate of 200W. How long does it take to boil all the water?

1) What is the Q to increase the T of ice to 0 ºC?
2) What is the Q to melt the ice?
3) What is the Q to increase the T of the water to 100 ºC ?
4) How long does it take to boil all the water?

Specific heat c=1.0 for water, 0.50 for ice

The latent heat of fusion for water is 334,000 J/kg = 80 cal/g

The latent heat of vaporization in water is 2,260,000 J/kg = 540 cal/g

1cal=4.186 J